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(54) BOREHOLE APPARATUS USING REINFORCED-RESIN PIPE STRINGS

(71) We, MANCAR-TRUST, a Joint Stock Company organised under the laws of Liechtenstein, of Vaduz, Liechtenstein, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates to a borehole apparatus of the type comprising coaxially disposed outer and inner pipe strings each comprising pipe lengths connected together by couplings.

Such borehole apparatus serves the purpose of conveying liquid and/or gaseous media in boreholes, and usually consist of steel which material is heavy in weight. When sinking wells or boreholes to major depths, the heavy weight of steel provides a considerable disadvantage because in deep wells the size of the steel pipes used is several times larger, e.g. between 3 and 5 times, the minimum requirements based upon the loads that are to be expected at large depths. The load factors which determine the dimensions of steel pipes has hitherto included the internal pressure, the external pressure and the dead weight of the apparatus. A significant factor that enters into such load calculations is the temperature at which the arrangement will operate. Further problems which must be considered in the design of deep well-drilling arrangements is the nature of the medium that is to be conveyed, which may cause corrosion of the plant necessitating frequent replacement of lengths of pipes constituting the pipe string; e.g. every three years or less. In the transport of crude oil, other problems arise because of waxy deposits which gradually block the pipe lengths completely.

The present invention is directed to means to obviate such difficulties wherein pipe-strings, instead of being constituted by steel pipes, are made up of lengths of pipe formed of glass-fibre reinforced resin, as hereinafter described. Pipe-strings formed of such pipes can be used in deep-drilling arrangements having a depth at least 1000 metres and operating under internal pressures of at least 100 atmospheres.

The invention provides borehole apparatus including co-axially arranged inner and outer pipe-strings disposed in a borehole each of the said pipe-strings comprising pipe lengths formed from glass fibre-reinforced resin which are positively coupled by coupling means one to another, wherein each pipe-string is reinforced around the entire circumference thereof by glass fibres extending in the axial direction of the pipe-string, whereby when the pipe-string is fully loaded in the axial and radial directions the axial/radial strain ratio of the said pipe-string is less than 0.95.

Apparatus according to the invention has the advantage over comparable equipment consisting of pipes made of steel or similar alloys, that it is very much lighter in weight, and may be as low as one fifth of comparable arrangements made of steel, and may be used at very great depths without major difficulties. For example the loading conditions at such major depths can be sustained if according to a further feature of the invention the pipe-strings and the said coupling means have around the respective circumferences thereof at least one radial reinforcing means adapted to reinforce the said strings against radial forces. In particular a layer of webbing or fabric may be disposed between the outer pipe surface and the said axial reinforcing means. Furthermore a radial reinforcement consisting of a cross-wound binding may be provided at least on one side of a said radial reinforcing means, preferably having an angular pitch between 10° and 80° which pitches may be different. Preferably at least two cross-wound bonding layers are provided at least one binding layer being present on each side of the said radial reinforcing means, the cross-windings having

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a different angular pitch. The said axial reinforcing means, and if desired the said radial reinforcing means may comprise glass fibres of different gauge which may amount to between 8 and 120 ends. Such a constitution does not significantly increase the overall weight of the total arrangement.

Alternatively or in addition to these reinforcements further axial and further radial reinforcing means may be provided externally of the said radial reinforcing means, and possibly further radial reinforcing means may be provided externally of such further axial reinforcing means. Such further means may be mats or fabrics, and further reinforcement may be provided by at least one layer, preferably of thickness between 2 and 10 mm. consisting of a mixture of filler and resin extending over all pipe lengths and couplings, such a step likewise bringing about an improvement particularly in the strength of the arrangement to resist external pressure. Such a mixture of filler and resin may comprise a synthetic resin e.g. 70% by weight of a synthetic resin, mixed with sand having a grain size preferably between 0.8 and 2 mm. The thickness of the said filler resin layer is preferably between 2 and 10 mm. As a matter of practicality the synthetic resin used for such a mixture of resin and filler should be readily bondable with the synthetic resin forming the base of the individual pipe lengths.

The resin used in the individual pipe lengths constituting the strings is preferably a low viscosity epoxy resin, for instance 100 parts by weight of which may be mixed with 100 parts by weight of a hardener, e.g. tetrahydrophthalic anhydride, and 1.5 parts by weight of an accelerator, e.g. tridimethylaminomethyl-phenol. Other suitable resins for forming the base of the individual pipe lengths may be unsaturated polyester resins, methacrylate resin, phenolic resins, furan resins, melamine resins, silicone resins, copolymers of butadiene styrene with vinyl toluene, and vinyl ester resins. Resins based on polyester bisphenol A-fumarates may also be used. Instead of anhydride hardeners, amine hardeners and other hardeners suitable for epoxy resins could be employed.

The individual pipe lengths may be provided inside and outside with an organic or inorganic liner, for example synthetic rubber, polyvinyl chloride or polyethylene.

The individual pipes and all couplings of the pipe-strings may be so dimensioned that their wall thicknesses progressively decrease in the axial direction from above downwards, this progressive decrease in wall thickness being accompanied by a progressive decrease of the axial and other reinforcement. In this context it should be noted that for the convenience of drilling in practice it is preferred that the individual pipe lengths should not be unduly long and that the individual couplings may conveniently have the form of screw couplings. The ends of the individual pipe lengths may be provided with external threads for the reception of a threaded external coupling sleeve. Alternatively the ends of the individual pipe lengths may be flared and provided with internal threads for engaging an internal threaded bush preferably formed at each end with a flange for the interposition of a sealing ring. Such an internal threaded bush may also be formed with a central axial flange to create possibilities for the provision of further sealing rings between the individual pipe lengths that are to be joined. Such sealing rings must are high pressure seals.

For borehole apparatus according to the invention to be permanently installed it is advisable to coat the external surface of the outer pipe with sand. Such a coating of sand on the outer surface of the outer pipe enables the pipe to be grouted into position with cement, grouting being preferably accomplished by pouring the cement mix through the interior of the outer pipe and then forcing it upwards into the annular space between the outside of the pipe and the borehole by means of a circulating fluid. The sand coating facilitates bonding of the cement mix to the external surface of the outer pipe.

According to yet another feature of the invention the inner pipe is in part a double-walled pipe comprising an outer wall spaced away from the inner wall and being provided at least in portions with elastic flexibility so that it can be lifted away from the inner wall and brought into contact with the outer pipe, said outer wall being connected to the inner wall by an airtight joint at a point axially below such a portion. This form of construction in which the outer wall of the inner pipe, at least in the zones which are elastically flexible, may consist of a tube of elastomeric material enveloping the inner wall, provides the means of easily checking the equipment for leaks during its installation as well as later during use. Moreover, the proposed construction of the inner pipe as a double-walled pipe has the advantage that the inner pipe is additionally secured from any possible leakage in course of use of the equipment. For checking the leak-tightness of the equipment all that is needed is to fill the annular space between the two walls of the inner pipe for instance with air under pressure, the result being that the elastically flexible zone(s) of the outer wall of the double-walled pipe will expand and form a barrier in the annular space between the inner and the outer pipes,

thus permitting leakages in the system to be detected by checking the pressures. The individual tube lengths forming the outer wall of the inner, double-walled pipe are located preferably at the level where the couplings are situated which connect the inner walls of such an inner pipe. The couplings between the tube lengths may be welded joints.

A tube of elastomeric material of the proposed kind may envelop the inner wall of such a double-walled pipe. In such a construction the elastically flexible portion in each length may be of thinner gauge than the remainder. Alternatively, the outer wall may consist of a flexurally rigid material in the regions where no barrier is to be formed. This has the advantage of providing a reliable air duct as far as the region where an elastically flexible portion of the wall permits a barrier to be formed in the annular space between between the inner and outer pipes.

Several embodiments of the invention are schematically shown in the accompanying drawings in which

Fig. 1 is a schematic representation of a portion of a borehole apparatus according to the invention,

Fig. 2 is a cross section of a single pipe length in apparatus according to Fig. 1, shown on a larger scale,

Figs. 3 to 6 are schematic representations of different methods of constructing pipe lengths in apparatus according to Fig. 1,

Fig. 7 is a portion of a borehole apparatus according to another embodiment of the invention.

The borehole apparatus according to the invention of which a longitudinal portion is schematically shown in Figure 1 consists of coaxially disposed outer pipes 1 and inner pipes 2, each composed of a major number of individual lengths which are glass-fibre-reinforced pipes coupled together at 3 by schematically indicated coupling means. According to the invention these pipes 1, 2 including all the coupling means 3 are provided with an axial reinforcement of fibres capable of taking up the entire load to which the pipe may be exposed, said fibres minimising the longitudinal elongation of the equipment and causing the ratio of axial strain to radial strain to assume a value less than 0.95, preferably about 0.8. In Figure 1 reference number 4 indicates a cement mix for bonding the outer pipe 1 to the wall of the hole 5, adhesion of the mix to the outside surface of the outer pipe 1 having been created by the provision of a coating of sand on the outside of said pipe. This cement mix is filled into the annular space between the outer pipe 1 and the inner pipe 2 and then forced by a circulating fluid from the bottom upwards into the annular space between the external surface of the outer pipe 1 and the wall of the hole 5.

In the cross-section illustrated in Fig. 2, reference number 6 indicates the resin base of which the individual pipe lengths are made. 7 is the axial reinforcement around at least one circumferential line. In the embodiment shown this reinforcement is embraced by radial reinforcements 8 on two circumferential lines and by a final axial reinforcement 9 outside the outer-most radial reinforcement.

In Figures 3 to 6 alternative arrangements of the reinforcement of individual pipe lengths are schematically shown. In each drawing, 6 is the resin base which may possibly be coated with an organic or inorganic liner material. Moreover, in the several drawings 7 is a radially inner and 9 a radially outer axial reinforcement, whereas 8 are two radial reinforcements interposed between the axial reinforcements. In Figure 3 the radially outer axial reinforcement 9 is embraced by two additional radial reinforcements 8^1. This latter feature is also present in the embodiments according to Figs. 4 to 6.

In the embodiment according to Fig. 4 the two axial reinforcements 7 and 9 are each underlaid with a reinforcing webbing or fabric 10. In the embodiment according to Figure 5 the radial reinforcements 8 between the axial reinforcements 7 and 9 are provided on each side with a cross-wound binding 11 and 12, an arrangement which imparts particularly high strength to the pipe. The pitch of the cross-wound bindings 11 and 12 may vary between 10 and 80° and the pitch of the binding 12 may possibly differ from that chosen for the cross-wound binding 11.

Furthermore, the embodiment according to Figure 6 indicates that the axial reinforcement 9 which is radially on the outside may be underlaid with a layer 13 consisting of a mixture of filler and resin in order to save fibre material without losing strength, particularly for withstanding external pressure.

Figure 7 is an embodiment of the borehole apparatus according to the invention in which the inner pipe is a double-walled pipe. In this embodiment the inner pipe consists of a flexurally rigid inner wall 14, the individual lengths of inner wall being joined together by couplings 3^1. Radially spaced away from this inner wall is an outer wall 15 which may have sections that are of elastically yielding construction, such as the portion marked 16, axially below which this outer wall is joined to the inner wall 14 by an airtight connection 17 so that by the introduction of compressed air into the annular space 18 between the outer wall 15 and the inner wall 14 the yielding portion 16 of the outer wall can be elastically

expanded to form a barrier in the annular space 18 between the outer pipe 1 and the inner pipe. When such a barrier has been created it is possible, by monitoring the pressures, to find out whether the equipment is air-tight. Such a check can therefore be made with simple means section-by-section in the course of installation, or during operation. The outer wall 15 of the double-walled inner pipe may for instance be formed by a tube of elastomeric material which envelops the inner wall, and which has a reduced wall thickness where a barrier of the afore-mentioned kind is to be formed. The individual tube lengths may be welded together as indicated at 19.

The axial and radial reinforcing fibres of each individual pipe length and/or coupling may be in the form of continuous or parallel glass filaments arranged in close or contacting order and embedded in the resin material of the pipe lengths.

WHAT WE CLAIM IS:—

1. Borehole apparatus including coaxially arranged inner and outer pipe-strings disposed in a borehole each of the said pipe-strings comprising pipe lengths formed from glass fibre-reinforced resin which are positively coupled by coupling means one to another, wherein each pipe-string is reinforced around the entire circumference thereof by glass fibres extending in the axial direction of the pipe-string, whereby when the pipe-string is fully loaded in the axial and radial directions the axial/radial strain ratio of the said pipe-string is less than 0.95.

2. Apparatus according to Claim 1, wherein the said ratio is about 0.8.

3. Apparatus according to Claim 1 or Claim 2, wherein the pipe-strings and the said coupling means have disposed around the respective circumferences thereof at least one radial reinforcing means adapted to reinforce the said strings against radial forces.

4. Apparatus according to any of Claims 1 to 3, wherein a layer of webbing or fabric is disposed between the outer pipe surface and the said axial reinforcing means.

5. Apparatus according to Claim 3 or Claim 4, wherein further axial reinforcing means are provided externally of the said radial reinforcing means.

6. Apparatus according to Claim 5, wherein further radial reinforcing means are disposed around the said further axial reinforcing means.

7. Apparatus according to any of Claims 3 to 6, wherein a layer of cross-wound binding is disposed at least on one side of a said radial reinforcing means.

8. Apparatus according to Claim 7, wherein said cross-wound binding has an angular pitch between 10° and 80°.

9. Apparatus according to Claim 7 or Claim 8, wherein at least two cross-wound binding layers are provided at least one binding layer being present on each side of the said radial reinforcing means, the cross-windings having a different angular pitch.

10. Apparatus according to any of Claims 1 to 9, wherein a layer of webbing or fabric is disposed on the inside surface of an axial reinforcing means.

11. Apparatus according to any of Claims 1 to 10, wherein at least one layer of a filler-resin mixture is disposed around the circumference of the pipe-strings and the said coupling means.

12. Apparatus according to Claim 9, wherein the said filler resin mixture comprises a synthetic resin mixed with sand.

13. Apparatus according to Claim 12, wherein the said sand has a grain size between 0.8 and 2 mm.

14. Apparatus according to Claim 12 or Claim 13, wherein the thickness of the said filler-resin layer is between 2 and 10 mm.

15. Apparatus according to any of Claims 1 to 13, wherein at least one of the said axial and/or radial reinforcing means and/or the couplings comprise glass fibres of different gauge.

16. Apparatus according to any of Claims 1 to 15, wherein the resin component of the individual pipe lengths of the pipe-string is an epoxy resin incorporating a hardener.

17. Apparatus according to any of Claims 1 to 16, wherein the said individual pipe lengths of the pipe-string are provided inside and outside with an organic or inorganic liner.

18. Apparatus according to any of Claims 1 to 17, wherein the said pipe lengths of the pipe-strings and the said couplings have a wall thickness which progressively decreases in a downwards direction.

19. Apparatus according to any of Claims 1 to 18, wherein the inner pipe of the pipe-string is a double-walled pipe comprising an outer wall spaced radially away from the inner wall and being provided at least in portions with elastic flexibility so that it can be lifted away from the inner wall and brought into contact with the outer pipe, said outer wall being connected to the inner wall by an airtight joint at a point axially below such portion.

20. Apparatus according to Claim 19, wherein at least the elastically flexible part of the outer wall of the said inner pipe comprises a tube of elastomeric material enveloping the said inner wall.

21. Apparatus according to Claim 19 or Claim 20, wherein the inner wall of the said inner pipe is enveloped by the tube

of elastomeric material and that the elastically flexible portions of the tube are thinner than the remainder of the tube wall.

22. Apparatus according to any of Claims 1 to 21, wherein the external surface of the said outer pipe of the pipe-string is coated with sand.

23. Apparatus substantially as hereinbefore described and illustrated in any of the accompanying drawings.

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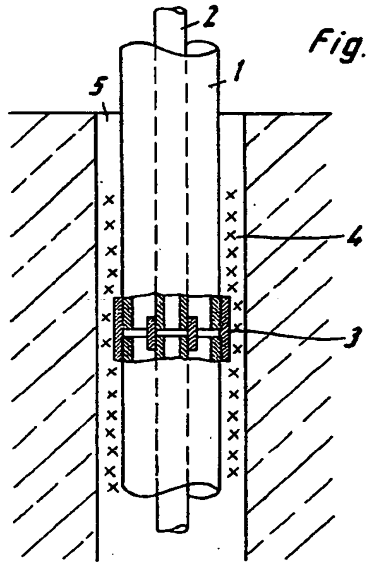

Fig. 1

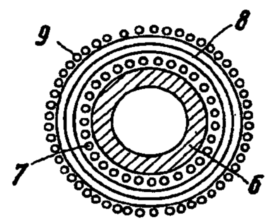

Fig. 2

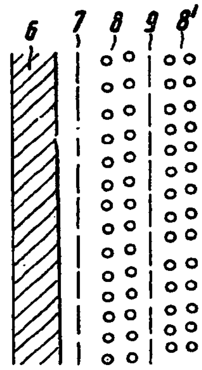

Fig. 3

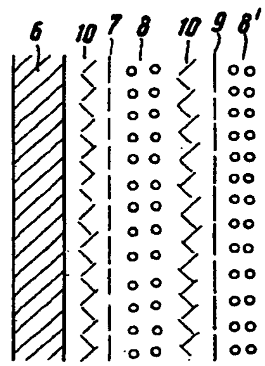

Fig. 4

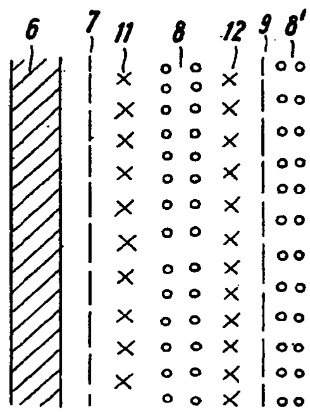

Fig. 5

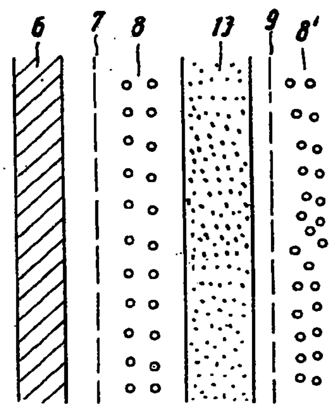

Fig. 6

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3 SHEETS This drawing is a reproduction of the Original on a reduced scale

Sheet 3

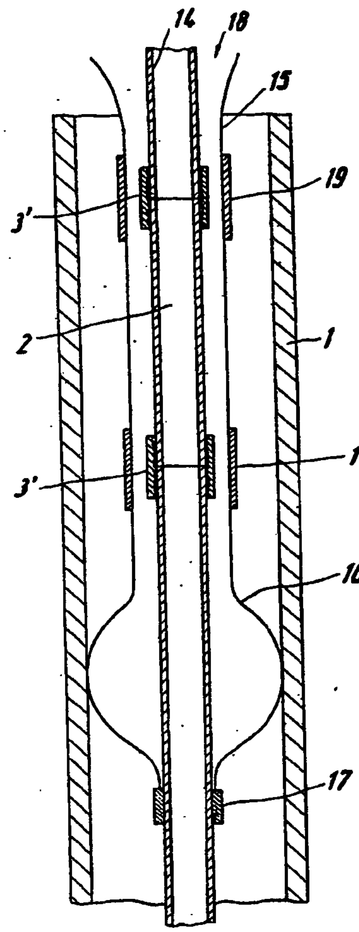

Fig. 7